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OPERATION NOUGAT II

SHOT DANNY BOY

PROJECT 2.4

MASTER

# SOME RADIOLOGICAL OBSERVATIONS AND CHARACTERISTICS OF FALLOUT DEBRIS FROM A NUCLEAR CRATERING EXPERIMENT, SHOT DANNY BOY




Harold M. Mork

K. H. Larson

R. A. Wood

B. W. Kowalewsky





University of California
School of Medicine
Laboratory of Nuclear Medicine
and Radiation Biology
Los Angeles, California


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ABSTRACT

The fallout pattern from a nuclear device buried in hardrock (basalt) at 33.5 meters below ground surface was delineated by ground survey from the edge of the ejecta out to 7.6 kilometers. An aerial radiometric survey further extended the fallout pattern to about 165 kilometers downwind from the detonation.

The distribution of radioactivity per unit area, mass per unit area, and radioactivity per unit mass and particle size were determined. There was little correlation between activity per unit mass and activity per unit area; specific activity varied inversely with particle size. Radioactive decay of samples from selected locations in the pattern showed negative slopes of about 1.3 for the time interval from H + 45 to H + 260 hours.

There was a significant increase in the less-than 44 micron size fraction with increase in distance from ground zero. More than 70 percent of the radioactivity was associated with this size fraction.

Limited data on radionuclides indicated some fractionation with distance.

ACKNOWLEDGMENTS

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# CHAPTER 1

# INTRODUCTION

## 1.1 OBJECTIVES

The objectives of this project were to determine certain physical and radiological characteristics of fallout from the detonation of a nuclear device buried in hardrock (basalt) at 33.5 meters below ground surface. Specifically, the studies were as follows:

(1) To extend the fallout pattern using ARMS I & II beyond the LRL and REECO Surveys.

(2) To determine the distribution of radioactivity as a function of total gamma activity per unit area, mass per unit area, gamma radioactivity per unit mass and per particle size fraction in samples obtained from granular fallout collectors prelocated in the predicted fallout pattern.

(3) To measure the gamma radioactive decay of samples from selected locations in the fallout pattern.

(4) To provide fallout samples to Lawrence Radiation Laboratory for radionuclide determinations and solubility studies.

(5) To study the interception and retention of fallout debris by foliage of native vegetation and to attempt to obtain a measure of fractionation of the fallout cloud as influenced by the terrain.

## 1.2 BACKGROUND

The Environmental Radiation Division of the Laboratory of Nuclear Medicine and Radiation Biology, University of California, Los Angeles, California (LNMRB) has participated in off-site fallout programs for over ten years (1, 2 & 3), and since the inauguration of the Plowshare Program, has been interested in the study of fallout from buried nuclear detonations.

Data and observations obtained from studies made at NTS by the field group of this laboratory indicate that for the different types of nuclear detonation, emphasis should be placed on the determination of the properties of the less-than 44 micron size fraction of fallout debris including its pattern of deposition in the biosphere, the degree of radionuclide fractionation with fallout time, the chemical properties, and the size distribution within this fraction.

Predictions made available by LRL, for nuclear cratering experiments indicated that the type of nuclear device, its placement for detonation, the characteristics of the media at shot point, the prevailing wind directions and speeds at various levels of the "cloud" would influence the apparent characteristics of fallout debris collected along the resultant pattern. Comparison of some of the data obtained by the UCLA field group from Shots Jangle Surface (S) and Underground (U), beyond 10 miles from ground zero, illustrate some of these differences in characteristics

of fallout. These differences were largely attributable to placement of the device. The S shot was about 4 feet above the soil surface whereas the U shot was buried 17 feet below the surface (References 1 & 4). (1) The average rate of decay of Shot S fallout debris collected at about 30 miles was significantly longer than for Shot U collected similarly. (2) Only glass-like beads were found in the Shot S debris, whereas the Shot U debris was irregularly shaped, very friable, dark colored particles. (3) The radioactivity from Shot U debris was about 10 percent soluble in water and 38 percent soluble in 0.1N HCl; the solubility of Shot S particles was estimated to be less than 2 percent in 0.1N HCl. (4). Using standard mechanical size analysis methods for soil, it was found that 80 percent of the radioactivity was associated with the 75 to 150 micron soil fraction for the Shot S debris samples collected about 30 miles from ground zero while 40 to 50 percent of the radioactivity was associated with the less-than 44 micron soil fraction for Shot U debris (samples collected at 12 and 35 miles from ground zero).

These and other studies indicate that each different type of nuclear cratering experiment requires carefully designed and integrated fallout studies in order that comparable reference data be available for the prediction of the radiological safety of future projects using nuclear devices.

# CHAPTER 2

# PROCEDURE

## 2.1 SHOT PARTICIPATION

UCLA contributed to the LRL program per LNMRB/CETO previous projects. Fallout studies were conducted from the edge of the ejecta to a distance of about 7.6 kilometers from ground zero for Shot Danny Boy. The acceptable primary fallout pattern was in the northerly sector of the Buckboard Mesa area between azimuth N40°W and N68°E from ground zero. Arcs and radial trails in this area were established by LRL to facilitate the location of fallout collection equipment and radiation surveys (Figure 2.1).

Shot Danny Boy was a nuclear device buried 33.5 meters below ground surface, Area 18, the Nevada Test Site (NTS). Detonation occurred at 1015 hours PST on 5 March 1962.

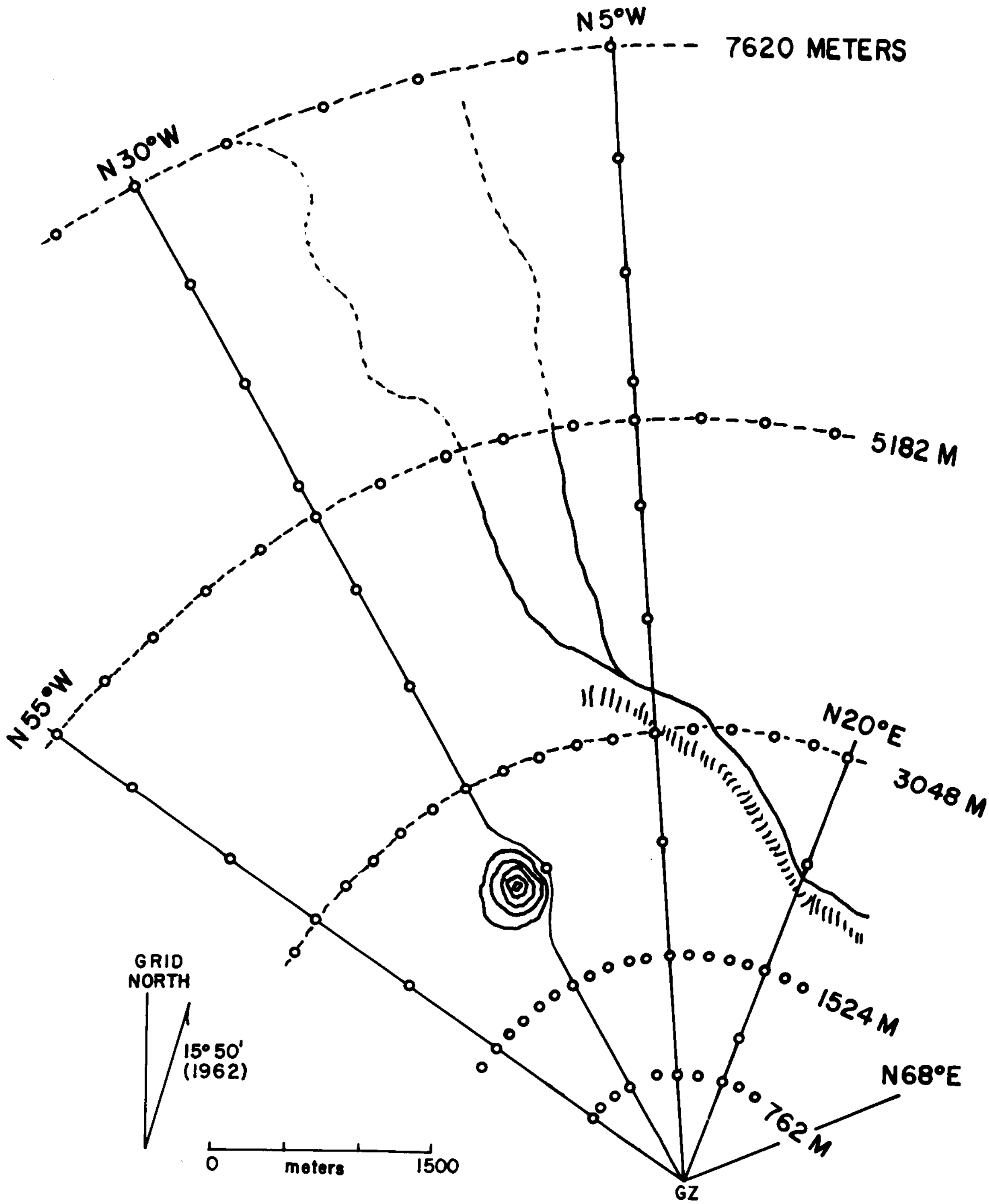
## 2.2 ORGANIZATION

Eight personnel from this laboratory conducted the fallout studies with additional manpower support from LRL and the U. S. Army Chemical Corps, Nuclear Defense Laboratory (NDL). Forty officers and men from Project 2.5 assisted this project with the fallout collections and the work in the processing laboratory.

## 2.3 PROJECT OPERATION PROCEDURES

Field teams from Project 2.5 prelocated granular fallout collectors on five arcs and six radials in the area of predicted

FIGURE 2.1 ARCS AND RADIAL TRAILS ESTABLISHED BY LRL


N 5°W
7620 METERS
N 30°W
5182 M
N55°W
N20°E
3048 M
GRID
NORTH
15° 50'
(1962)
1524 M
N68°E
762 M
0
meters
1500
GZ

fallout. After the detonation the fallout trays were recovered and returned to the laboratory for processing. Ground radiological surveys were made from the edge of the ejecta out to 7.6 kilometers from ground zero by Project 2.5.

Aerial radiometric surveys were made in the areas beyond 8000 meters by the U. S. Geological Survey (ARMS I) and Edgerton, Germeshausen & Grier (ARMS II). ARMS I was associated with this laboratory during Operation Plumbbob (Reference 3) and Hardtack II (Reference 9). Pre-shot aerial background levels of radioactivity were determined along the laterals in the intermediate (ARMS II) and the long range (ARMS I) sectors in a northerly direction from ground zero. Beginning at H + 5 hours and continuing through D + 3 days, flights were made to delineate the pattern and measure the levels of gamma activity at 500 feet above ground surface across the areas in which fallout occurred.

## 2.4 LABORATORY PROCEDURES AND INSTRUMENTATION

Procedures and instrumentation developed by this group during previous field operations were used for this study. These have been described in detail in various reports (References 2,3 & 5). One modification was made in the pellet processing procedure. A new method of pellet washing replaced the original particle separator of prior field studies (References 6 & 7).

2.4.1 Fallout Collectors

Fallout debris was sampled by granular collectors (GC). Details of the GC assembly and associated procedures have been described previously (References 5, 6 & 7).

Briefly, the GC consisted of a flat metal tray (29 x 47 x 3/8 inch deep) divided into 2 sample areas each 4.3 square feet. Each half of the tray was lined with a Mylar plastic sheet (E. I. Dupont Co.) folded to approximately fit the edges of the tray and held in place with "binder" clips. About 3.5 lbs. of 3/16 inch diameter plastic pellets (polyethylene), which provided a matrix to trap the fallout debris, were spread uniformly on each half of the plastic covered tray. All trays were placed on the ground surface as far from the influence of shrubs as possible and oriented with their long dimension parallel to the lateral.

When the trays were recovered, the Mylar sheets were gathered around the pellets making a package and tied. These individual packages were placed in paper bags, labelled and transported in cartons to the laboratory for radio-assay and particle sizing.

2.4.2 Laboratory Processing of Fallout

A vibration-flow method of pellet washing to remove the fallout debris from the granular matrix was field tested during Operation Nougat, Shot Danny Boy. This vibration-flow method (Reference 7) proved to be more efficient than the original particle separator (Reference 6 and Appendix Table A.4).

The fallout debris from the GC's was recovered from the matrix (pellets) using a procedure similar to that used previously except for the washing process. The new washing assembly consisted of a screen 18 inches in diameter placed in a spring-mounted sieving pan actuated by an electric motor vibrator. The pellets were simultaneously stirred and subjected to mechanical vibration during the washing procedure. Then, the IPA-fallout-debris-suspension was drained through a weighed 44 micron sieve (U. S. No. 325) which retained all particles greater than 44 microns in diameter. Additional fresh IPA was sprayed over the pellets to displace any retained or adhering alcohol.

The material retained on the 44 micron sieve was washed with IPA again, the screen and its contents were dried under a heat lamp, weighed, and the gamma activity was determined.

The < 44 micron material in the drain-pot was removed by filtering the IPA suspension through a weighed membrane filter (Millipore Filter Corp.). This residue was finally washed using IPA applied by a wash bottle, dried under a heat lamp, weighed, and the gamma activity determined.

## 2.5 CALCULATION OF RESULTS

The following calculations were made to obtain gamma activity per square meter.

(1) The observed counts per minute on processed granular collector samples were corrected for instrument background and

coincidence loss to give net counts per minute. A coincidence correction was made on samples with an observed count rate above 500,000 counts per minute.

(2) The net counts per minute were corrected to a common time of H + 100 hours using an average measured decay slope of -1.3[8].

(3) Finally, the net counts per minute at H + 100 hours were corrected for sample geometry using a $Cs^{137}$ reference source and divided by the area of the collector surface to give disintegrations per minute per square meter. These activity per unit area values were divided by the respective mass per unit area to obtain the specific activity in disintegrations per minute per unit mass.

## 2.6 RELIABILITY OF PROCEDURES

The reliability of procedures employed in processing fallout debris from Shot Danny Boy and subsequent field operations has been reported (References 5 and 6). It was 85 percent for the activity determinations.

## 2.7 SAMPLES FOR RADIOCHEMISTRY

Samples for radionuclide determinations and solubility studies were prepared for air shipment to LRL as soon as possible after processing. The initial samples (12 processed and 1 unprocessed) were delivered to the LRL warehouse at NTS 8 days after the detonation. Three days later a second group (17 processed and 42 unprocessed) was delivered for shipment. Duplicates of these samples (unprocessed) were later forwarded to LRL also.

# CHAPTER 3

# RESULTS AND DISCUSSION

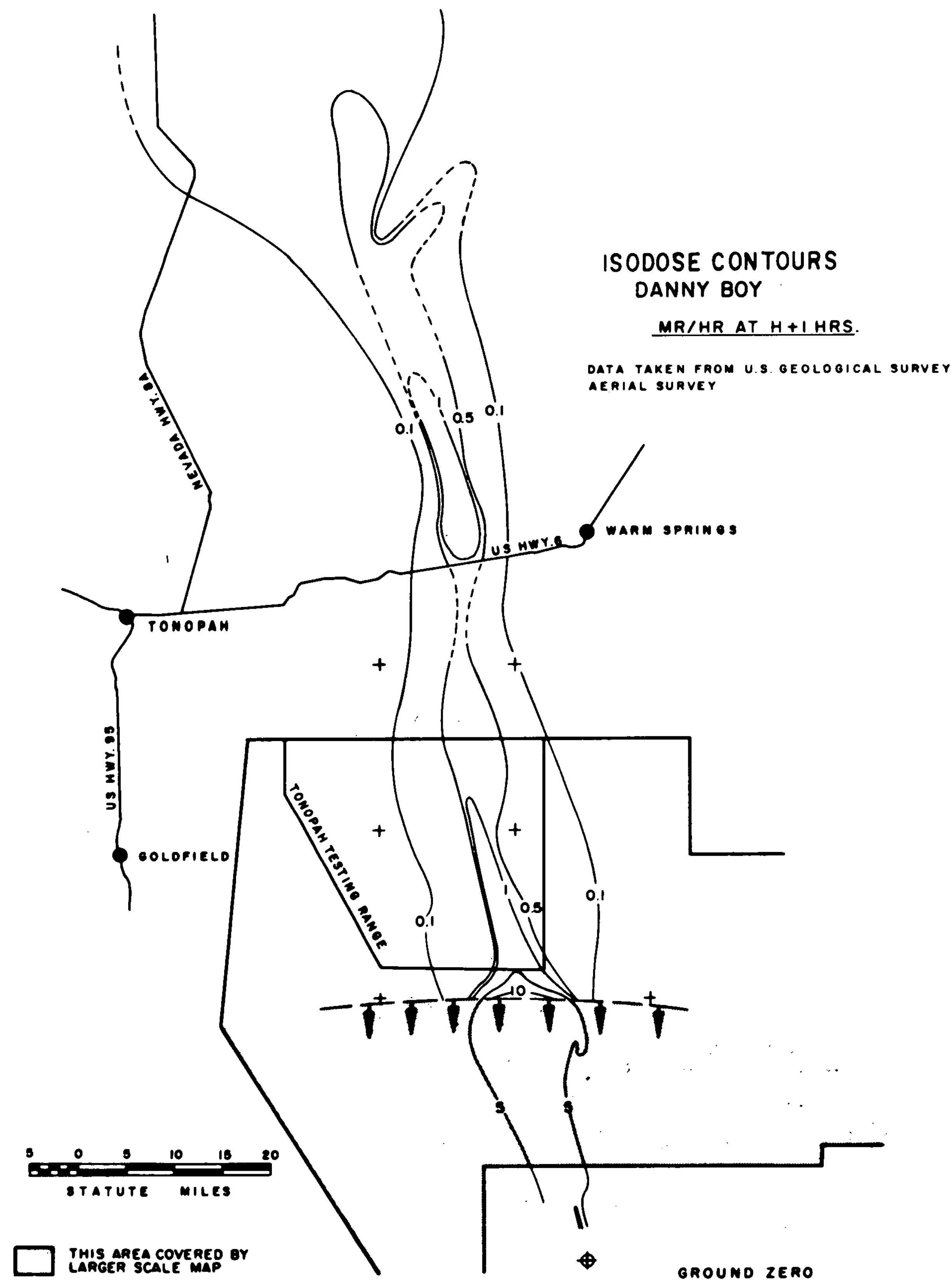
## 3.1 FALLOUT SAMPLE RECOVERY

Samples from 42 stations were recovered on D-day, and 30 more were collected on D + 1 and D + 2 days. High radiation levels permitted the collection of only a limited number of samples from the arcs at 762 and 1524 meters from ground zero.

## 3.2 FALLOUT PATTERN CHARACTERISTICS

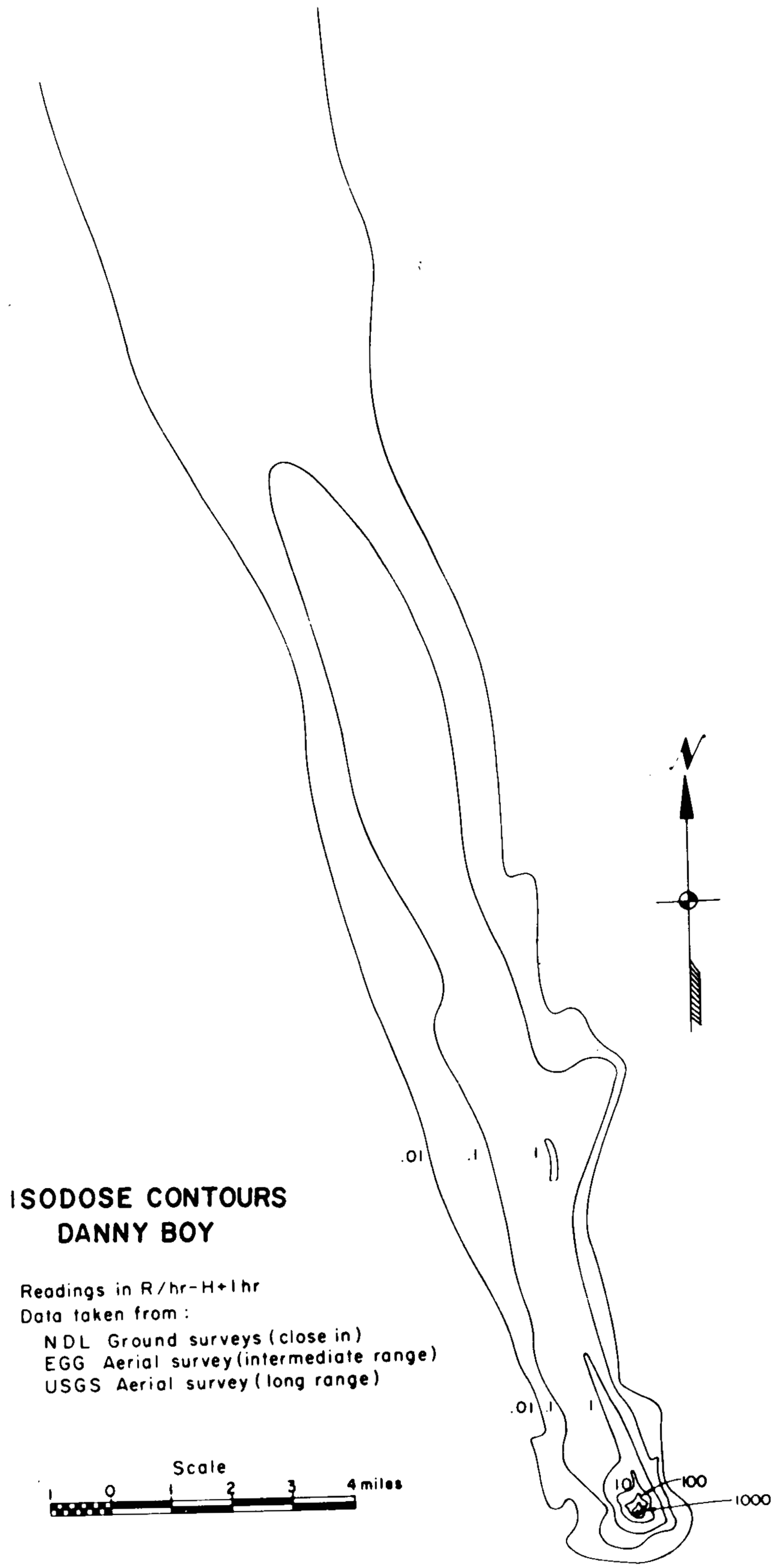
A composite of data obtained by NDL, Project 2.5 ground radiation survey (Reference 8), and by measurements of activity on the fallout collectors, was used to delineate the fallout pattern out to the 7620 meter arc. Beyond that distance, the EG&G/CETO aerial survey recorded the radioactivity in the intermediate range (7 to 39 km from GZ) during the period H + 5 to H + 7 hours. The long range fallout (40 to 168 km from GZ) was measured by the USGS/CETO aerial survey. Mr/hr values, corrected ($t^{-1.3}$) to H + 1 hour based on ground survey readings along the roads and trails at 3 feet above the ground surface, and aerial survey measurements converted to mr/hr (77,000 c/s at 500 feet per mr/hr at 3 feet) were plotted as a function of distance from GZ. The resulting radiation isopleths, Figures 3.1 and 3.2, show the area of distribution of the radioactive debris out to a distance of more than 165 kilometers.

FIGURE 3.1 ISODOSE CONTOURS, INTERMEDIATE RANGE, SHOT DANNY BOY



ISODOSE CONTOURS
DANNY BOY
MR/HR AT H+1 HRS.
DATA TAKEN FROM U.S. GEOLOGICAL SURVEY AERIAL SURVEY
NEVADA HWY. 8A
US HWY. 6
WARM SPRINGS
TONOPAH
US HWY. 95
GOLDFIELD
TONOPAH TESTING RANGE
0.1
0.5
0.1
0.1
1
0.5
0.1
10
5
5
5 0 5 10 15 20
STATUTE MILES
THIS AREA COVERED BY LARGER SCALE MAP
GROUND ZERO

FIGURE 3.2 ISODOSE CONTOURS,LONG RANGE, SHOT DANNY BOY




**ISODOSE CONTOURS**
**DANNY BOY**

Readings in R/hr-H+1 hr
Data taken from:
NDL Ground surveys (close in)
EGG Aerial survey (intermediate range)
USGS Aerial survey (long range)

## 3.3 FALLOUT CHARACTERISTICS

Samples from 30 GC locations bracketing the midline of radiation were selected for processing. The midline was determined from dose rate data obtained by Project 2.5 [8].

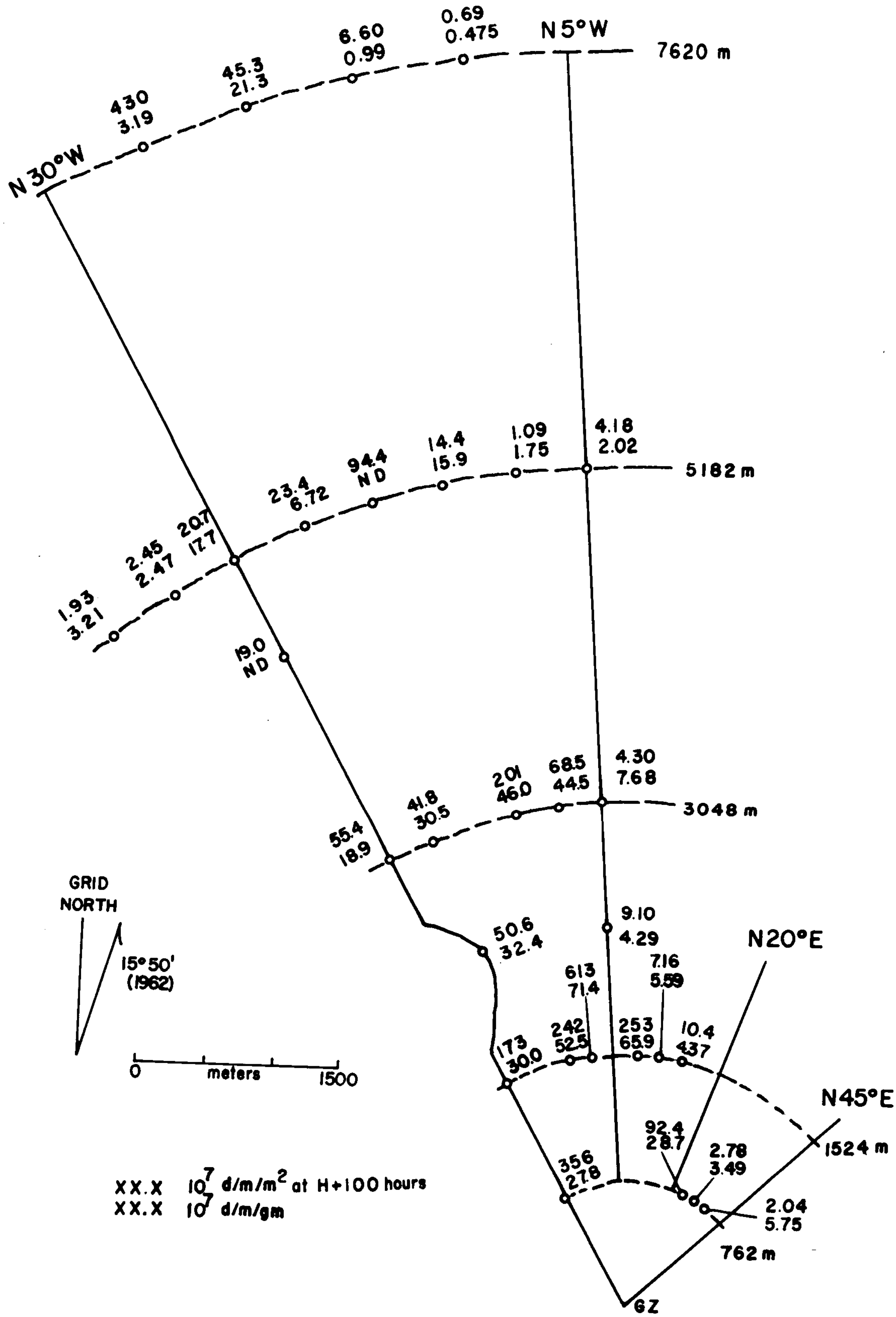
A duplicate sample of each GC was radioassayed for total gamma activity to determine the radioactivity per unit area. From these, samples were selected for gamma decay determinations (Section 3.3.3 and Figure 3.5); the other samples were processed routinely and separated into greater-than and less-than 44 micron size fractions. Each of the fractions was assayed for its gamma activity and weighed to determine the mass per fraction. Samples were then packaged and made ready for delivery to LRL at NTS.

### 3.3.1 Gamma Activity per Unit Area and Per Unit Mass

The results obtained from the GC's located along the fallout pattern are shown in Figure 3.3. The unit area activities ranged from over $10^9$ d/m/m$^2$ on an azimuth of N10$^\circ$W at the 1524 meter lateral to less than $10^7$ d/m/m$^2$ on the same azimuth at the 7620 meter lateral. On the intervening laterals the maximum values occurred farther to the west; i.e., N15$^\circ$W at 3048 meters; N20$^\circ$W at 5182 meters; N20$^\circ$W at 7620 meters. In general, the unit area activity decreased with distance from ground zero.

The activity per unit mass (specific activity) also decreased at greater distance from ground zero, but there was little

FIGURE 3.3 RADIOACTIVITY PER UNIT AREA AND PER UNIT MASS AS RELATED TO DISTANCE FROM GROUND ZERO


N30°W
N5°W
7620 m
5182 m
3048 m
1524 m
762 m
N20°E
N45°E
GZ
GRID NORTH
15°50' (1962)
0 meters 1500
430 3.19
45.3 21.3
6.60 0.99
0.69 0.475
4.18 2.02
1.09 1.75
14.4 15.9
94.4 ND
23.4 6.72
20.7 17.7
2.45 2.47
1.93 3.21
19.0 ND
4.30 7.68
68.5 44.5
201 46.0
41.8 30.5
55.4 18.9
9.10 4.29
50.6 32.4
613 71.4
7.16 5.59
173 30.0
242 52.5
253 65.9
10.4 4.37
92.4 28.7
2.78 3.49
2.04 5.75
356 27.8
XX.X $10^7$ d/m/m$^2$ at H+100 hours
XX.X $10^7$ d/m/gm

correlation between the two. More mass was associated with the larger size fraction along the midline with the smaller size material in greater proportion near the edges of the pattern.

The specific activity levels on the N10$^{\circ}$W azimuth ranged from 71 x $10^7$ d/m/gram at 1524 meters to less than $10^7$ d/m/gram at 7620 meters from ground zero. On the intervening laterals the maximum values, like those for the unit area activity, occurred farther to the west.

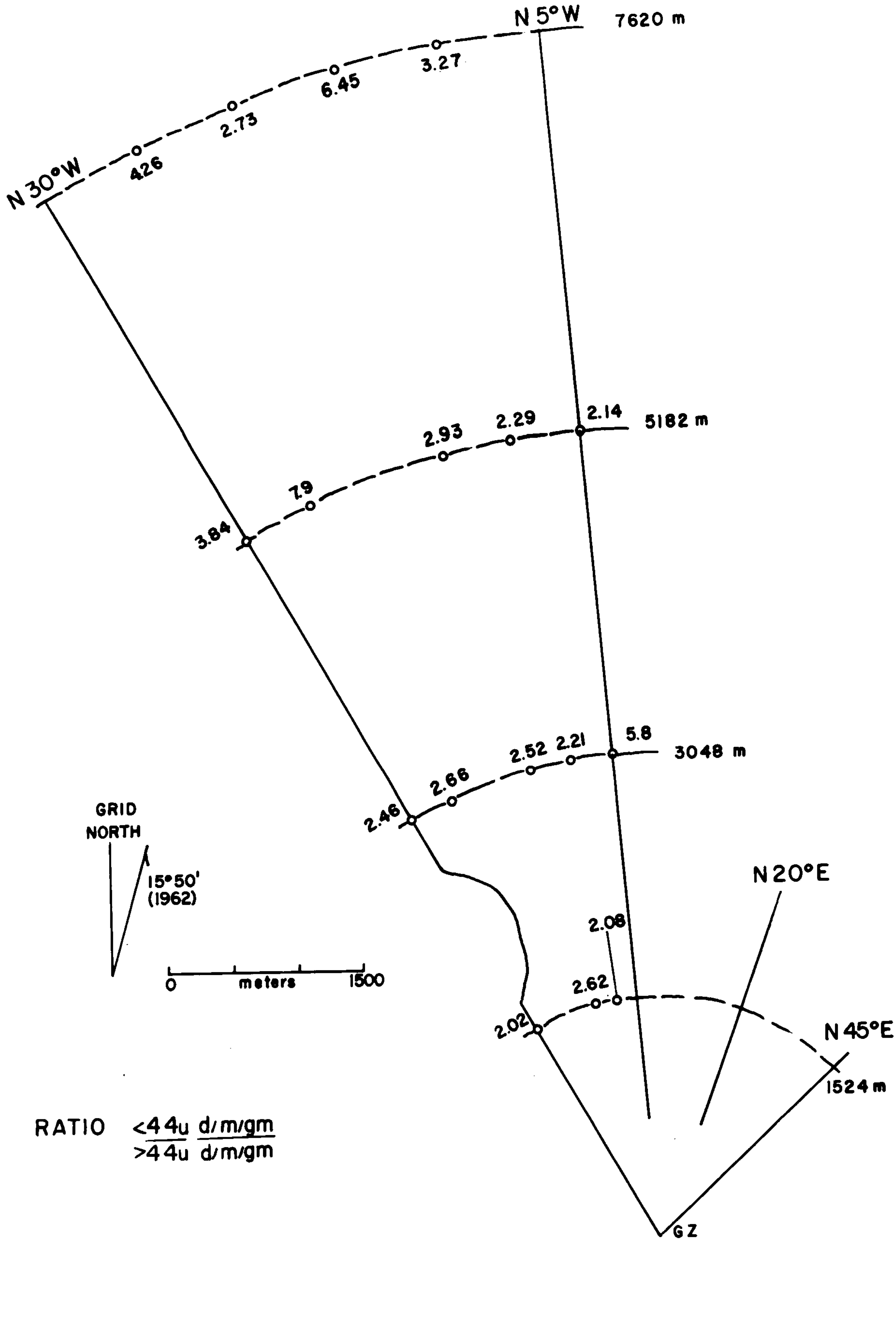
3.3.2 Specific Activity and Particle Size

An analysis of the distribution of specific activity in two particle size fractions suggest that the specific activity varied inversely with the particle size. The specific activities for the less-than 44 micron size fractions were greater than those for the greater-than 44 micron size fractions by a factor from 2 to almost 8, depending on the distance and the azimuth from ground zero (Figure 3.4). On an activity-mass basis all of the samples had more than 50 percent of the activity associated with the less-than 44 micron size fraction; but only 35 percent had more than 50 percent of the mass in the less-than 44 micron fraction. The proportion of the mass in the smaller size fraction increased appreciably with increase in distance from ground zero.

3.3.3 Radioactive Decay

Radioactive decay of selected samples showed negative slopes of

FIGURE 3.4 VARIATION OF SPECIFIC ACTIVITY AND PARTICLE SIZE WITH DISTANCE FROM GROUND ZERO



N 5°W
7620 m
3.27
6.45
2.73
426
N 30°W
2.14
5182 m
2.29
2.93
7.9
3.84
5.8
3048 m
2.21
2.52
2.66
2.46
GRID
NORTH
15°50'
(1962)
0
meters
1500
N 20°E
2.08
2.62
2.02
N 45°E
1524 m
GZ
RATIO
<44u d/m/gm
>44u d/m/gm

about 1.3 for the time interval from H + 45 to H + 260 hours (Figure 3.5). This compared very favorably with the value of 1.32 for Project Sedan.

3.3.4 Interception and Retention of Fallout Debris

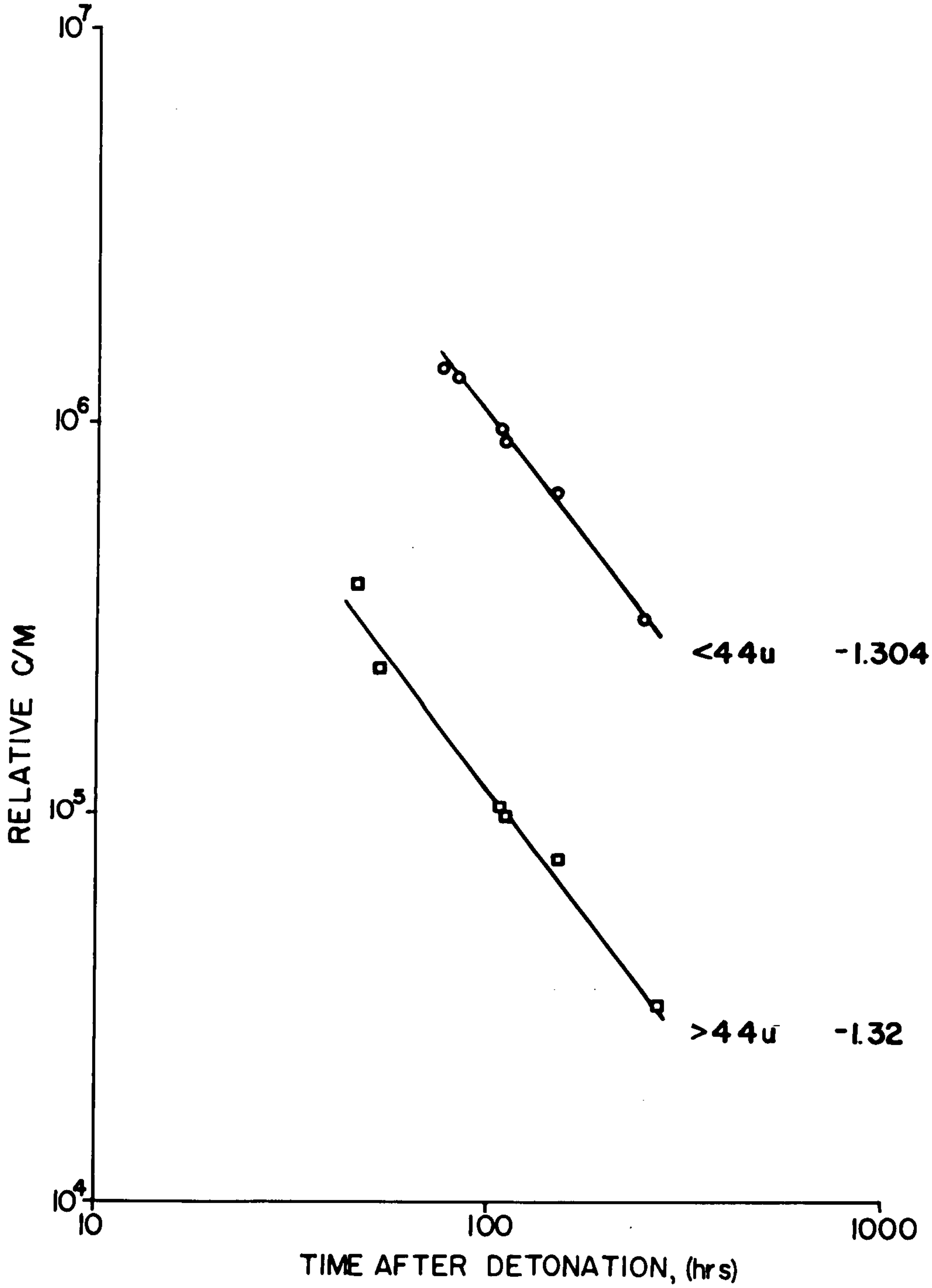
Inclement weather during the night following the detonation curtailed plans to study the interception and retention of fallout debris by foliage of native vegetation and to obtain a measure of fractionation of the fallout cloud as influenced by the terrain.

3.4 Radionuclides and Particle Size

Some fractionation of the cloud occurred as evidenced by very limited data on only three fallout samples. There was a significant increase in the proportion of three radionuclides in the less-than 44 micron particle size fraction with increase in distance from ground zero. The ratio of the radioactivity in the

$\frac{\text{less-than 44 u}}{\text{greater-than 44 u}}$ for $Sr^{90}$ increased ten-fold in a distance of about 700 meters; and the ratio for $Cs^{137}$ and $Ce^{144}$ changed by factors of 8 and 4, respectively, in a distance of about 1500 meters (Table 3.1).

FIGURE 3.5 GAMMA DECAY CURVES FOR SELECTED SAMPLES



$10^7$
$10^6$
$10^5$
$10^4$
RELATIVE C/M
<44u -1.304
>44u -1.32
10
100
1000
TIME AFTER DETONATION, (hrs)

Table 3.1. Change in Particle Size with Distance from GZ

| Radionuclide | Ratio* of $\frac{\text{Dis/m in} <44\ \text{u}}{\text{Dis/m in} >44\ \text{u}}$ | | |
|---|---|---|---|
| | 762 m | 1524 m | 2286 m |
| $Sr^{90}$ | 0.23 | 2.60 | - |
| $Cs^{137}$ | 1.74 | 3.26 | 14.5 |
| $Ce^{144}$ | 0.23 | 0.40 | 0.91 |

* Dis/m, disintegrations per minute at T=0

# CHAPTER 4

# CONCLUSIONS

## 4.1 CONCLUSIONS

1. Adequate data were obtained from ARMS I & ARMS II to extend the fallout pattern beyond the LRL and REECO surveys to about 165 kilometers.

2. There was little correlation between the activity per unit mass and the activity per unit area on the corresponding laterals across the fallout pattern.

3. Radioactive decay of samples from selected locations in the pattern showed negative slopes of about 1.3 for the time interval from H + 45 to H + 260 hours.

4. There was a significant increase in the proportion of the less-than 44 micron mass over the greater-than 44 micron mass with increase in distance from ground zero.

5. More than 70 percent of the activity was associated with the less-than 44 micron size fraction.

6. Limited data on radionuclides indicated a very significant increase in the enrichment of $Sr^{90}$, $Cs^{137}$ and $Ce^{144}$ in the less-than 44 micron particle size fraction with increase in distance from ground zero.

# APPENDIX A

DATA ON DECAY, UNIT AREA ACTIVITY, UNIT AREA MASS, PARTICLE SIZE AND RESIDUAL ACTIVITY ON GRANULAR COLLECTOR MATRIX AFTER PROCESSING

Table A.1 RADIOACTIVITY PER UNIT AREA AND PER UNIT MASS

Activity corrected to H + 100 hours. ND, not done

| Azimuth from GZ | Distance from GZ | Gamma Activity Unit Area | Gamma Activity Unit Mass |
|---|---|---|---|
| degrees | meters | $10^7$ dis/min/$m^2$ | $10^7$ dis/min/g |
| N40° W | 5182 | 1.93 | 3.21 |
| N35° W | 5182 | 2.45 | 2.47 |
| N30° W | 762 | 356 | 27.8 |
| | 1524 | 173 | 30.0 |
| | 3048 | 55.4 | 18.9 |
| | 4572 | 19.0 | ND |
| | 5182 | 20.7 | 17.7 |
| N25° W | 2286 | 50.6 | 32.4 |
| | 3048 | 41.8 | 30.5 |
| | 5182 | 23.4 | 6.7 |
| | 7620 | 4.3 | 3.2 |
| N20° W | 5182 | 94.4 | ND |
| | 7620 | 45.3 | 21.3 |
| N15° W | 1524 | 242 | 52.5 |
| | 3048 | 201 | 46.0 |
| | 5182 | 14.4 | 15.9 |
| | 7620 | 6.6 | 0.99 |
| N10° W | 1524 | 613 | 71.4 |
| | 3048 | 68.5 | 44.5 |
| | 5182 | 1.1 | 1.8 |
| | 7620 | 0.69 | 0.48 |
| N5° W | 2286 | 9.1 | 4.3 |
| | 3048 | 4.3 | 7.7 |
| | 5182 | 4.2 | 2.0 |
| N | 1524 | 253 | 65.9 |
| N 5° E | 1524 | 7.2 | 5.6 |
| N10° E | 1524 | 10.4 | 4.4 |
| N25° E | 762 | 92.4 | 28.7 |
| N30° E | 762 | 2.8 | 3.5 |
| N35° E | 762 | 2.0 | 5.8 |

Table A.2 UNIT AREA ACTIVITY AND MASS DISTRIBUTION ACCORDING TO PARTICLE SIZE

Activity corrected to H + 100 hours.

| Azimuth from GZ | Distance from GZ | Gamma Activity/Unit Area $<44\mu$ | Gamma Activity/Unit Area $>44\mu$ | Mass/Unit Area $<44\mu$ | Mass/Unit Area $>44\mu$ |
|---|---|---|---|---|---|
| degrees | meters | $10^5$ dis/min/$m^2$ | | mg/$m^2$ | |
| N30° W | 1524 | 10670 | 6670 | 2530 | 3240 |
| | 3048 | 4230 | 1310 | 1640 | 1290 |
| | 5182 | 1440 | 630 | 440 | 730 |
| N25° W | 3048 | 3140 | 1030 | 720 | 650 |
| | 5182 | 1780 | 570 | 1040 | 2430 |
| | 7620 | 360 | 80 | 710 | 640 |
| N20° W | 7620 | 2910 | 1630 | 840 | 1290 |
| N15° W | 1524 | 16700 | 7540 | 2060 | 2250 |
| | 3048 | 13700 | 6390 | 3070 | 2300 |
| | 5182 | 980 | 460 | 380 | 530 |
| | 7620 | 500 | 160 | 2250 | 4420 |
| N10° W | 1524 | 46300 | 15060 | 5100 | 3480 |
| | 3048 | 4350 | 2500 | 690 | 850 |
| | 5182 | 90 | 23 | 400 | 230 |
| | 7620 | 50 | 17 | 700 | 750 |
| N 5° W | 3048 | 350 | 80 | 240 | 320 |
| | 5182 | 310 | 120 | 1140 | 930 |

Table A.3 GAMMA DECAY DATA

| N30° W at 1524 meters (<44μ) | | N30° W at 1524 meters (>44μ) | |
|---|---|---|---|
| H + hr | $10^6$ c/m/Sample | H + hr | $10^6$ c/m/Sample |
| 74.8 | 13.8 | 45.4 | 3.90 |
| 82.8 | 13.1 | 51.8 | 3.32 |
| 105.3 | 9.30 | 104.2 | 1.04 |
| 107.3 | 8.98 | 107.3 | 1.00 |
| 147.8 | 6.65 | 147.8 | 0.76 |
| 242.2 | 3.35 | 267.5 | 0.33 |

Table A.4 RADIOACTIVITY REMAINING ON GRANULAR COLLECTOR MATRIX AFTER FOUR WASHES

Total gamma radioactivity corrected to H + 100 hours. ND, not done.

| Sample Location | Replicate | Total Gamma Radioactivity | Gamma Radioactivity Remaining on Granules |
|---|---|---|---|
| from GZ | | $10^5$ dis/min/$m^2$ | Percent |
| N30° W, 762 meters | A | 3410 | 1.1 |
| | B | 3490 | 6.1 |
| N30° W, 1524 meters | A | ND | ND |
| | B | 1960 | 5.0 |
| N25° W, 2286 meters | A | 540 | 7.9 |
| | B | 590 | 8.9 |
| N 5° W, 2286 meters | A | 950 | 6.8 |
| | B | ND | ND |

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